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BASIC ATTRIBUTES TESTS (BAT) SYSTEM: DEVELOPMENT OF AN AUTOMATED TEST BATTERY FOR PILOT SELECTION

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In 1955, the Air Force discontinued apparatus-based testing as a component of its aircrew selection and classification system due to administrative problems. Since then, the Air Force has relied on paper-and-pencil test batteries such as the Air Force Officer Qualifying Test to select pilot and navigator trainees. Although the aircrew selection system without apparatus testing has demonstrated a reliable relationship with pilot training outcome, concern with attrition rates in pilot training, along with the development of computer technology, produced a renewed interest in the utility of psychomotor testing. As a result, a computer-based testing system, the Basic Attributes Tests (BAT) system, was developed to assess psychomotor skills, as well as a variety of psychological and cognitive attributes that are believed to be related to flight training performance. The events leading up to the development of the BAT system and its hardware and software specifications are reviewed. A brief summary of validation studies of the various tests also is provided.

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SUMMARY

Recent efforts to reduce attrition rates in Undergraduate Pilot Training have resulted in the development of an experimental computer-administered test battery, the Basic Attributes Tests (BAT) system. The test battery assesses psychomotor skills, as well as a variety of cognitive/perceptual abilities and psychological/attitudinal characteristics that are believed to be related to flight training performance. The events leading up to the development of the BAT system and its hardware specifications are reviewed. A brief review of validation studies of the various BAT tests is provided.

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PREFACE

This project was conducted under Work Unit 77191845 in support of RPR-78-11, Selection for Undergraduate Pilot Training, issued by the Air Training Command.

The groundwork for this project resulted from the efforts of several people in addition to those referenced in the bibliography. Major Hector M. Acosta performed a preliminary analysis of the Basic Attributes Tests (BAT) battery. Ms. Thao Nguyen was helpful in providing information regarding the development of BAT software and general BAT procedures.

Appreciation also is extended to Mr. Ed Watkins and his staff for their efforts in preparing the data files and programming the analyses, and to Ms. Christine Carvajal for administrative support.

Finally, the author extends thanks to Dr. Jeffrey E. Kantor, Major John Quebe, and Lt Colonel William Ercoline for their guidance and support during this project.

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I. INTRODUCTION

Background

In 1955, the Air Force discontinued apparatus-based testing as a component of its aircrew selection and classification system. For over a decade prior to its termination, a variety of testing devices had provided perceptual and motor abilities measures that were useful in predicting the outcome of preliminary flight training. The decision to terminate this type of testing was made primarily because of difficulty in the administration of these tests.

Problems with the reliability of the older apparatus systems developed when the Air Force decentralized the selection process by conducting testing at several sites. The decline in reliability was attributed to the difficulty in keeping the electro-mechanical apparatus testing devices correctly calibrated and the test administration procedures consistent across test sites. After considering cost-effectiveness issues, the Air Force decided that a recently validated paper-and-pencil battery, the Air Force Officer Qualifying Test (AFOQT), would compensate adequately for the lost predictive utility of the apparatus-based tests (McGrevy & Valentine, 1974).

Three primary sources provide candidates to the current aircrew selection system; namely, the Air Force Academy (AFA), the Air Force Reserve Officer Training Corps (AFROTC), and the Air Force Officer Training School (OTS). In addition to medical requirements, selection procedures for both AFROTC and OTS rely heavily on minimum qualifying scores on the AFOQT. All three sources require that candidates either complete a light aircraft flying course conducted by the Air Force or obtain a private pilot's license prior to receiving a commission and assignment to Undergraduate Pilot Training (UPT). Although the aircrew selection system without apparatus testing has demonstrated a reliable relationship with pilot training outcome, concern with attrition rates in pilot training, along with the development of computer technology, produced a renewed interest in the utility of psychomotor testing (Long & Varney, 1975).

Purpose

The purpose of this report is to document the development of the Basic Attributes Tests (BAT) system and to provide some preliminary results regarding its usefulness.

The need to improve the selection of flight training candidates, along with recent advances and innovations in computer technology and psychological theory/methodology, have combined to stimulate interest in the reinstatement of apparatus testing. For example, Hunter and Thompson (1978) demonstrated the usefulness of psychomotor measures in predicting flight training performance. As a result, the project to develop the BAT system was initiated at the Air Force Human Resources Laboratory (AFHRL) in July 1981, as a critical part of a larger research and development (R&D) program in aircrew selection and classification (Hunter, Maurelli, & Thompson, 1977; Long & Varney, 1975; McGrevy & Valentine, 1974).

The goal of the BAT project was to develop a computer-administered test battery to improve the selection of candidates for undergraduate pilot and navigator training. In addition to reducing the attrition rate for pilot and navigator training, it was hoped that the battery would help to identify candidates for early placement in specialized training programs (Specialized Undergraduate Pilot Training or SUPT, Specialized Undergraduate Navigator Training or SUNT). The

test apparatus had to be reliable, cost-effective, portable, and easy to use and maintain. Further, it was decided that the tests given by this device should assess psychomotor skills, as well as a variety of psychological and cognitive factors that are believed to be related to flying training outcome, such as field dependence/independence, information processing, short-term memory, and risk-taking behavior (Imhoff & Levine, 1981).

II. BAT DEVELOPMENT

BAT Hardware

The prototype BAT systems were installed at Lackland Air Force Base in 1982. In 1983, AFHRL decided to supplement the prototype BAT testing stations with more modern, high-speed, super-microcomputer-driven, transportable testing units. This decision was in keeping with the Air Force's earlier desire for decentralized testing. The resulting system, built under contract by Technical Solutions Inc., was designated the PORTA-BAT.

The PORTA-BAT, shown in Figure 1, is a complete, integrated, portable testing laboratory that features high-speed graphics, rugged single- and dual-axis joysticks, a data entry keypad, fixed and removable hard data storage disk drives, and a metal station enclosure designed to reduce environmental distractions during testing and to function as a shipping container for transporting the unit. The PORTA-BAT features a powerful super-microcomputer with high-speed, high-resolution graphics and communications features that permit networking or on-line data transfer to a monitoring station during testing. The operating system is directly adapted from UNIX, and most standard compilers are available with the PORTA-BAT. The PORTA-BAT supports either serial or parallel printers, and up to three additional terminals for concurrent program development or analysis of test data. Further, the unit comes equipped with a high-level graphics software package with C and FORTRAN callable graphics functions, the Regulus operating system, a C compiler, a FORTRAN compiler, and the software necessary for interfacing all attached devices. The technical specifications and architecture of the PORTA-BAT are provided in Table 1.

BAT Software

In addition to administering the tests in the battery, the BAT software provides quality control checks for the data, as well as supportive routines and commands.

Quality Control. Quality control checks consist of internal controls within each of the BAT tests that ensure the correct recording of all responses (keypad and joystick entry) and check program and external control routines. There are several internal quality control procedures to ensure that only the proper keys light up and are accepted as valid inputs when subjects are required to enter a response on the keypad. Also, a variety of program checks help to ensure the integrity of the data. These include checks for the number of data entries on a line, the length of the subject's social security number (used for subject identification), and completion of the tests. Checks are also made to ensure that keypad responses are within the proper range of values and made within time limits, response times are recorded correctly, and stray (accidental) keypad hits do not cause the recording of incorrect results on subsequent trials.

External quality control is provided by two software routines, RECAUD and AUDIT. RECAUD is a recovery and auditing routine. At the end of each testing session, RECAUD checks for errors in the BAT data set (e.g., data error, file length error, header error) and, if necessary, displays an error message on the screen to inform the test administrator. The AUDIT routine checks for any error that might occur before the data are sent to Brooks Air Force Base for analysis.

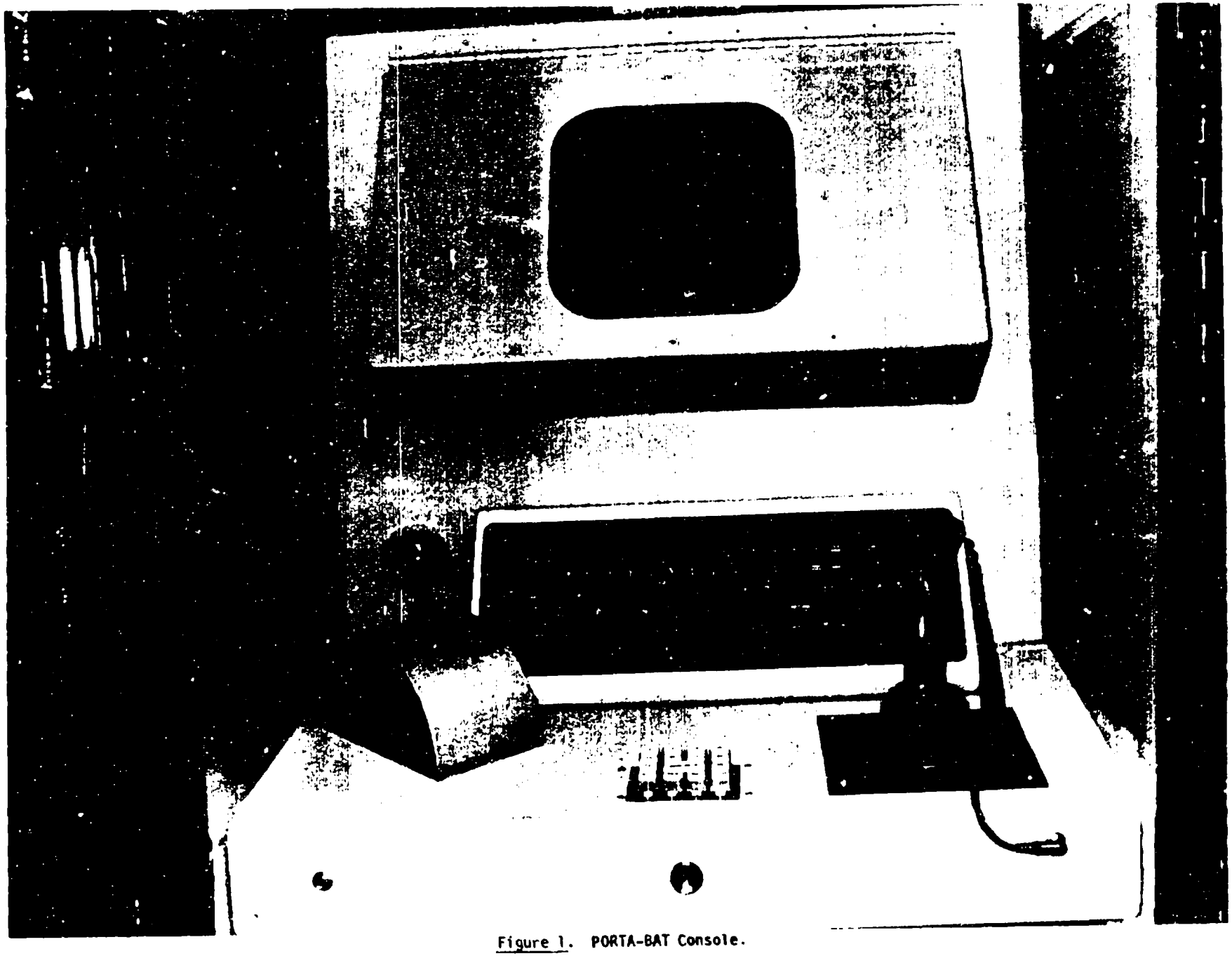

Figure 1. PORTA-BAT Console.

Table 1. PORTA-BAT Specifications and Architecture

Specifications

Processor

Type: Motorola MC68010 10 MHz
Memory Manager: Motorola MC68451
Memory: 512 KB MOS
Bus Structure: G-BUS
High-Speed Memory Bus
Graphics Bus
Local I/O Bus
Serial I/O: Four I/O Bus
Parallel I/O: Centronics Printer
Laboratory Parallel
Clock: Date/Time of Day/Real-Time
Counter-Timers: Two

Display

Resolution: 481 X 530
Size: 12-inch
Speed: 40,000 vectors/second
Refresh: 60 times/second
Display Planes: 4
Grey Levels: 16
Persistence: short

Cabinet

Height: 60 inches
Depth: 38 inches
Width: 31 inches
Construction: Heavy-Gauge Aluminum

Environmental

Temperature: 5 to 35 degrees C.
Humidity: 10% to 90% non-condensing
Altitude: 0 to 6,000 feet

Architecture Designer

Technical Solutions, Inc.
P.O. Box 1148
Mesilla Park, NM 88047
(505) 524-2125

5 MB Removable Disk Drive

APS Processor
- 512 KB
- 3 Serial Ports
- Printer Port
- Display

Graphics Co-Processor
- 481X530
- 4 Planes
- Fast

5 MB Fixed Disk Drive

A/D Convertible 11 Parallel

Custom Interface

2-Axis Joystick

1-Axis Joystick

Custom Keypad

Supportive Routines and Commands. Several additional supportive software routines are necessary in order to present the BAT tests. Most of the BAT tests involve the display of graphics on the screen for presenting stimuli and providing feedback. Each point and line of the displayed picture is drawn by several graphics routines. The graphics screen must be continually updated (refreshed) to keep the picture up-to-date with changes Also, timing routines are used to keep track of the subject's response time and the time of a stimulus event.

Command files are used to ensure the safe and efficient storage of data. For example, all of the subject's data files are copied onto the fixed internal disk of the BAT unit at the end of each test session. This practice secures the safety of the testing disk. Old data files are deleted on a routine basis by another command file in order to make room on the disk for data from the next BAT testing session.

Occasionally, a power shortage or system failure will result in a sudden halt (crash) in the middle of a BAT testing session. There are three ways to restart the system. The first is through the RECAUD routine, which makes it possible for the test administrator to restart the battery from the point where the subject's last valid data were received. In the second method, the test administrator uses a built-in directory to execute the command file and chooses the point at which to resume the test. To choose the appropriate command file, the administrator needs to know which test the subject last completed. The third way to restart the system is to administer each test individually, rather than allowing the unit to proceed through the battery automatically. If this method is chosen, the subject must inform the test administrator as each test is completed.

General BAT Procedures. Usually after every week to 10 days of testing, the data are transferred from the BAT disk to be checked and copied onto a magnetic tape. The data are audited to ensure their validity and accuracy, and the disks are cleaned so that they may be reused for the next testing period. When a BAT data set is completed (once every 3 to 4 months), these data are sent to Brooks Air Force Base for processing. Backup copies are kept to safeguard against any mishaps that may occur. The backup copies are destroyed only after the data have been processed successfully and audited for accuracy.

Current BAT Battery

Each of the tests in the BAT battery was adapted from tests in the research literature that were identified as potentially useful predictors of flying performance (Imhoff & Levine, 1981). The criteria used to select these tests included feasibility, interest of the test-taker, independence from other tests in the battery, construct validity, and minimal dependence on verbal materials for administration. The current BAT battery was designed to measure a variety of psychomotor skills, information processing abilities, and personality characteristics that are considered important in determining the suitability of a candidate for flight training. A summary of the BAT battery, which indicates for each test, the name, order, length, origin, and attribute measured, is provided in Table 2. Individual test summaries are provided below.

Test Battery Introduction. This interactive subprogram prompts the subject to provide background information (e.g., identity, age, gender), as well as personal history and attitudes related to flying.

Psychomotor Tests. Two tests are used to evaluate psychomotor abilities. The first, the two-hand coordination test, is a variation of a rotary pursuit test. The airplane (target) moves in an elliptical path on the screen at a rate of 20 cycles per minute. The rate of movement of the airplane within each cycle varies in a fixed sinusoidal pattern. The subject controls the movement of a small "gunsight" using a left-hand joystick for vertical movement of the gunsight and a right-hand joystick for horizontal movement of the gunsight. The subject's task is to keep the gunsight on the moving airplane. After receiving instructions, the subject completes a

Table 2. Basic Attributes Tests (BAT) Battery Summary

Test name	Adminstration time (min)	Reference	Attributes measured
1. Test Battery Introduction	15	-----	Biographical information
2. Psychomotor Tests			
a. Two-hand coordination (rotary pursuit)	10	Fleishman, 1964	Tracking and time-sharing ability in pursuit
b. Complex coordination (stick and rudder)	10	Fleishman, 1964; McGrevy & Valentine, 1974	Compensatory tracking involving multiple-axis continuous events
BREAK	2		
3. Dot Estimation	6	Mullins, 1962	Impulsiveness/decisiveness
BREAK	1		
4. Digit Memory	5	Sperling, 1960	Perceptual speed
BREAK	1		
5. Encoding Speed	15	Posner & Mitchell, 1967	Verbal classification
BREAK	2		
6. Mental Rotation	25	Shepard & Metzler, 1971	Spatial transformation and classification
BREAK	2		
7. Item Recognition	20	Sternberg, 1966	Short-term memory storage, search, and comparison
BREAK	2		
8. Immediate/Delayed Memory	25	Hunter, 1975	Continuous short-term memory storage and retrieval
BREAK	2		
9. Decision-Making Speed	20	Fleishman, 1964	Choice reaction time under varying degrees of uncertainty
BREAK			
10. Risk Taking	10	Slovic, 1966	Risk taking
BREAK	2		
11. Embedded Figures	15	Witkin, 1949	Field dependence/independence
BREAK	2		
12. Time Sharing	30	North & Gopher, 1976	Higher-order tracking ability, learning rate and time-sharing ability as a function of differential load
BREAK	2		
13. Self-Crediting Word Knowledge	10	Mullins, 1962	Self-assessment ability, self-confidence
BREAK	2		
14. Activities Interest Inventory	10	Mullins, 1962	Survival attitudes
BREAK	2		
15. Automated Aircrew Personality Profile	10	Dahlstrom, Welsh, & Dahlstrom, 1972	Personality factors to be determined
Total	258		

3-minute practice session and a 5-minute test. The measures of interest are horizontal and vertical tracking error scores and axis joystick movement rate scores.

The second test, complex coordination, uses a dual-axis joystick (right-hand joystick) to control the horizontal and vertical movement of a cursor. The left-hand joystick controls the left-right movement of a vertical "rudder bar" of light at the base of the screen. The subject's task is to maintain the cursor (against a constant horizontal and vertical rate bias) centered on a large cross fixed at the center of the screen, while simultaneously centering the rudder bar at the base of the screen (also against a constant rate bias). The instructions, practice, testing, and scoring are as in the first test.

The psychological factors assessed in the first test are low-to-moderate order tracking and time-sharing ability in pursuit. The second test assesses compensatory tracking ability involving multiple-axis continuous events.

Dot Estimation. Two boxes containing an arbitrary number of dots are presented simultaneously on the screen. One of the two boxes contains one more dot than the other. The subject's task is to determine, as quickly as possible, which box has the greater number of dots. The subject is not told to count the dots in each box, but is told only to decide as quickly and accurately as possible which has the greater number.

Reaction time and accuracy of response are recorded on each trial. This is the only test in the battery that has a fixed time limit (5 minutes, for a maximum of 55 trials). The psychological factor assessed by this test is impulsiveness/decisiveness.

Digit Memory. A string of four digits is presented simultaneously and in random order. The subject is instructed to respond by entering the digit string on a data entry keypad in the same order as presented. In addition to the recording of accuracy and overall response time, a measure of perceptual speed is taken by forcing the subject to press a special "enabling key" that activates the data entry keypad buttons on each trial.

The most conceptually important attribute measured by this test is perceptual speed. There are 20 trials, which require about 5 minutes to complete.

Encoding Speed. The subject is presented simultaneously with two letters and is required to make a same-different judgment about the letter pair. The judgment may be based on Physical identity (AA versus Aa), Name identity (AA versus AH) or Category identity (vowels versus consonants - AE versus AH).

The latency of the encoding judgment provides a measure of the speed of the cognitive encoding process. Latency differences indicate the speed of recoding. That is, the average reaction time for Name identity judgments minus the average reaction time for Physical identity judgments indicates the speed with which physical stimuli may be recoded to the level at which their names may be accessed.

Reaction time and accuracy of response (correct/incorrect) are recorded on each of the 96 trials (32 trials in each condition). The psychological factor involved in this test is verbal classification at several levels of cognitive operation.

Mental Rotation. The subject is presented sequentially with a pair of letters and is required to make a same-different judgment. The letter pair may be either identical or mirror images, and the letters may be either in the same orientation or rotated in space with respect to each other. A correct "different" judgment is associated with a mirror image pair and is not dependent on the relative rotation of the two letters.

In order to perform the test, the subject must form a mental image of the first letter (no longer displayed) and perform a point-by-point comparison with the second letter (which remains on the display). In addition, when the letters are rotated with respect to each other, the subject must mentally rotate the mental image of one letter into congruence with the other prior to making the comparison.

Speed and accuracy of response are recorded on each of the 72 trials. The psychological factors assessed by this test are spatial transformation and classification.

Item Recognition. In this test, a string of one to six digits is presented on the screen. The string is then removed and followed, after a brief delay, by a single digit. The subject is instructed to remember the initial string of digits, then to decide if the single digit was one of those presented in the initial string. The subject is instructed to respond by pressing a keypad button marked "yes" if the single digit was in the string or another marked "no" if the digit was not in the string. The instructions inform the subject to work as quickly and accurately as possible. Speed and accuracy of response are recorded on each of the 48 trials.

Short-term memory storage, search, and comparison operations are the underlying psychological factors for this test.

Immediate/Delayed Memory. In this test, the subject is presented with a sequence of digits and required to respond by indicating the digit that occurred either one or two digits previously. The one-back and two-back subtests have two parts. In the first part, the digits are presented for 1/2 second, followed by a 2-second inter-stimulus interval. In the second part, the inter-stimulus interval is 5 seconds. Thus, for both subtests, part one deals with "immediate" memory and part two with "delayed" memory.

There are 25 trials in each level of test (one- versus two-back) by length of latency (2 versus 5 seconds) condition, which results in 100 trials. As with the other tests, response time and accuracy are recorded on each trial.

This test assesses continuous short-term memory storage and retrieval operations.

Decision-Making Speed. In this choice reaction time test, the subject is presented with one of several alternative signals. The subject is required to respond to the signal with the matching response as quickly as possible. The critical manipulation in this test is the amount of uncertainty that must be resolved in order to make the response decision. When an increased number of potential alternatives are introduced, greater uncertainty exists and the decision is made more slowly. This test consists of four parts.

In subtest one, the subject knows both where and when a signal is to occur; in subtest two, the subject knows where but not when; in subtest three, when but not where; and finally, in subtest four, the subject knows neither where nor when. Within each subtest there are three parts. In part one, two potential signals and responses are defined. There are four potential signals and responses in part two and eight potential signals and responses in part three. Therefore, degree of uncertainty of signal is manipulated in three ways: location of occurrence, time of occurrence, and number of signals/responses. There are 12 trials within each part of each subtest, resulting in 144 trials (12x3x4). Response time and accuracy of response (correct/incorrect) are recorded for each trial.

The decision-making speed test assesses a variety of psychological factors. These include simple choice reaction time under varying degrees of information load and spatial and temporal uncertainty, as well as low-level cognitive and high-level sensory-perceptual motor involvement.

Risk Taking. In this test, 10 boxes are presented in two rows of five boxes each. The subject is told that 9 of the 10 boxes contain a reward, whereas one of the boxes is a "disaster" box. The subject is allowed to select the boxes one at a time. If the selected boxes contain a payoff, the subject is allowed to keep it; but if the subject chooses the disaster box, all of the payoff earned on that trial is lost. The average number of boxes selected provides an index of the subject's tendency for taking risks when making decisions.

Response time per choice and number of boxes chosen are recorded on each of the 30 trials. Unknown to the subject, there is no "disaster box" (i.e., no risk) for 12 of the 30 trials. This method was used in order to obtain a clean measure of risk-taking behavior, as performance on the "disaster box" trials may be affected by chance.

Embedded Figures. The subject is presented with a simple geometric figure and two complex geometric figures. The test is to decide which of the two complex figures has the simple figure within it and to indicate a choice by pressing the button corresponding to the figure. Speed and accuracy of response are recorded on each of 30 trials.

This test assesses the psychological factor of field dependence/independence.

Time Sharing. During a series of 10, 1-minute trials, the subject is required to learn a compensatory tracking test. To perform this test, the subject must anticipate the movement of a marker on a screen and operate a control stick to counteract that movement in order to keep the marker aligned with a fixed central point. Test difficulty is adjusted throughout the test, depending on the subject's performance on the test. The control dynamics are a combination of rate and acceleration components. The "disturbance" factor is a quasi-random summed sinusoidal forcing function.

After these "tracking only" trials, the subject is required to track while cancelling digits that appear at random intervals and locations on the screen. A digit is cancelled when the subject presses the corresponding button on the keypad. A "cross-adaptive" logic forces the subject to respond to digits within 4 seconds after their appearance. These dual-task trials occur in two 3-minute blocks. The information processing load gradually increases during these trials. The time-sharing test ends with a final 3-minute block of "tracking only" trials. There are a total of 19 1-minute trials (10 tracking only, six dual-task, and three more tracking only).

The effects of the secondary task loads are reflected in the pattern of level of difficulty changes caused by the adaptive logic that holds tracking error constant. The measure of interest for this test is the level of difficulty at which the subject can perform consistently.

This test assesses a variety of psychological factors including higher-order tracking ability, and learning rate and time-sharing ability as a function of differential task load.

Self-Crediting Word Knowledge. This test is essentially a vocabulary test wherein the subject is presented with a "target" word and five other words from which its closest synonym must be chosen. There are three blocks of 10 questions each. The target words become increasingly difficult with each successive block. Subjects are informed of this increasing difficulty and required to make a bet prior to each block as to how well they expect to do. Response time and accuracy are recorded on each of the 30 trials.

This test assesses self-assessment ability and self-confidence.

Activities Interest Inventory. This test is designed to determine the subject's interest in various activities. The subject is presented with 81 pairs of activities and is asked to choose between them. The subject is told to assume that he/she has the necessary ability to perform

each activity. The activity pairs force the subject to choose between tasks that differ as to degree of threat to physical survival (sometimes subtly, sometimes not). The measures of interest are the number of high-risk options chosen and the amount of time required to choose between pairs of activities. The psychological factor assessed by this test is survival attitudes.

Automated Aircrew Personality Profile. This test is a questionnaire that examines the subject's attitudes and interests. The subject is presented with 66 questions, each requiring a choice between two alternatives. The subject is instructed not to spend time pondering responses, but to give the first natural answer as it comes. The questionnaire is a traditionally formatted personality inventory specially compiled in cooperation with the Air Force School of Aerospace Medicine and targeted for aircrew selection and classification.

The personality factors assessed by this test are undetermined currently.

III. VALIDATION STUDIES

Several of the tests in the BAT battery have already been evaluated in terms of their ability to predict various flight training performance measures and final training outcomes. Only the psychomotor abilities tests have demonstrated a strong relationship with success in UPT, advanced training assignment (fighter or non-fighter aircraft), and in-flight performance scores (Bordelon & Kantor, 1986; Kantor & Bordelon, 1985).

Scores on several of the cognitive/perceptual abilities tests have shown a relationship to advanced training assignment and in-flight performance but not to UPT final outcome. Subjects who made quick, consistent, and accurate responses on these tests were more likely to be recommended for a fast-jet assignment on completion of UPT (Carretta, 1987a, 1987c, 1987d, 1987e).

Performance on the personality/attitudinal tests has not been related strongly with either final training outcome or advanced training assignment. Only the test of self-confidence, Self-Crediting Word Knowledge, appeared to contribute to predicting completion of training, with successful candidates showing more caution (Carretta, 1987b; Carretta & Siem, 1987). The Automated Personality Profile currently is being revived.

The psychomotor tests of the BAT battery are under consideration as adjuncts to the Air Force UPT candidate selection system, and are being used currently for operational selection by the Air National Guard. The results of analyses of the cognitive/perceptual tests suggest that they may be most useful when selecting pilot candidates for specialized advanced training assignments (fighter or non-fighter).

IV. FUTURE DIRECTIONS

Several new computer-administered tests have been developed recently to complement the original BAT battery. In contrast to the original battery, which includes many simple cognitive/perceptual tests, many of these newer tests assess dual-task performance (e.g., perceptual vigilance, resource allocation, scheduling). Other new tests measure abilities not assessed by the original battery, such as kinesthetic memory, pattern recognition, perceptual defensiveness, rate and time estimation, and persistence.

As computer technology and psychological theory advance, computer-administered testing holds great promise as both a training and selection tool (e.g., computer adaptive testing, intelligent tutoring).

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